iVES OENO One vine & wine

DOI: https://doi.org/10.20870/oeno-one.2025.59.2.8484

OPEN ACCESS

ENOLOGY ORIGINAL RESEARCH ARTICLES

A novel application of the consumer rejection threshold method to the design of binary red wine blends prepared from traditional and fungus-resistant varieties

Caroline Paire[1,2], Foued Cheriet[1], Alain Samson[3], Christian Chervin[4], Audrey Arino[5], Gabriel Ruetsch[5], Estelle Ithurralde[6], Olivier Geffroy[2,*]

[1] MoISA, Université de Montpellier, Institut Agro Montpellier, 2 place Pierre Viala, 34000 Montpellier, France
[2] PPGV, Université de Toulouse, Ecole d'Ingénieurs de Purpan, 75 voie du TOEC, 31076 Toulouse, France
[3] INRAE, Unité expérimentale de Pech Rouge, 11430 Gruissan, France
[4] LRSV, Université de Toulouse, INP-ENSAT, Avenue de l'Agrobiopôle, 31326 Auzeville-Tolosane, France
[5] Les Vignobles Foncalieu, Domaine de Corneille, 11290 Arzens, France
[6] Les Grands Chais de France, Domaine de la Baume, 34290 Servian, France

Article number: 8484

**correspondence:*
olivier.geffroy@purpan.fr

Associate editor:
Sophie Tempère

Received:
16 January 2025

Accepted:
11 June 2025

Published:
25 June 2025

This article is published under the **Creative Commons licence** (CC BY 4.0).

Use of all or part of the content of this article must mention the authors, the year of publication, the title, the name of the journal, the volume, the pages and the DOI in compliance with the information given above.

ABSTRACT

Fungus-resistant grape (FRG) varieties obtained through interspecific hybridisation, are currently seen as a credible solution for reducing the use of pesticides in viticulture. One possibility is to include wines made from FRG in blends prepared from traditional varieties. Such addition is likely to negatively affect consumer's liking notably in red blends as red wines made from FRG may exhibit higher acidity, lower tannin content and stability given their high protein levels. This study aimed to apply the Consumer Rejection Threshold (CRT) method to determine to which extent red FRG wines can be incorporated into blends. Two red FRG wines, made from Vidoc and Artaban, were selected for the study and blended with a Merlot wine. After a first experiment consisting of identifying detection thresholds for FRG wines in a blend for untrained and expert panellists, a second experiment based on paired preference tests following the CRT method was conducted with consumers only. The detection thresholds were estimated for untrained subjects at 24.9 % *v/v* for Artaban, and 14.1 % *v/v* for Vidoc, highlighting a lower sensitivity than experts for which Artaban and Vidoc were detected at 6.9 % and 7.7 % *v/v*, respectively. During the second experiment, blends containing between 25 % and 60 % *v/v* of Artaban were less preferred than the single-variety Merlot wine but neutrally perceived over 60 % *v/v*. Surprisingly, Vidoc blends were neutrally perceived in comparison with Merlot for all the levels of incorporation evaluated, suggesting the existence of distinct clusters of consumers. Four groups of preferences were identified through Principal Component Analysis (PCA) and Hierarchical Agglomerative Clustering (HAC). Among these groups, only one representing 21 % of panellists, composed of a larger proportion of daily wine drinkers who identified themselves as novices in wine, showed a marked preference for Merlot over Vidoc blends. Overall, our results show the absence of a major sensory obstacle for the incorporation of the two studied FRG wines in Merlot blend which indicates a good consumer acceptability of these wines and encourages the wine industry to use FRG red wines for blending or in single *cuvée*.

KEYWORDS: fungus-resistant grape varieties, red blends, Merlot, Vidoc, Artaban, consumer acceptability

INTRODUCTION

Sustainability has become a major concern in the wine industry over the last decades (Wei *et al.,* 2023). The growing awareness among producers and consumers has spurred the sector to innovate, leading to an acceleration in breeding programs notably for fungal resistance (Borrello *et al.,* 2021; Paire *et al.,* 2024). Such fungus-resistant grape (FRG) varieties, also sometimes called tolerant varieties, are the result of interspecific hybridisation, combining the organoleptic qualities of *Vitis vinifera* with the natural resistance of American or Asian species (Töpfer *et al.,* 2011). Thanks to successive backcrosses with different *Vitis vinifera* cultivars to limit homozygosity, these varieties own a genome of more than 95 % belonging to the species *Vitis vinifera*, which enables one to combine both aroma and taste quality and disease tolerance (Borrello *et al.,* 2021). The planting of FRG is dynamic worldwide, notably in France with 2,270 hectares under vine in 2023 (Torregrosa *et al.,* 2024). According to the official French catalogue, forty new resistant varieties are registered, either permanently or temporarily, and available for planting by winegrowers and this number is set to increase (www.plantgrape.fr).

The availability of these varieties on the French market is increasing rapidly which is the consequence of recent changes in regulations (Borrello *et al.,* 2021). Indeed in 2018, the varieties of interest for adaptation purposes (VIFA) French directives opened the way to the introduction of new grapevine varieties into protected designations of origin (PDOs). Since December 2021, EU regulation 2021/2117 has allowed the production of PDO wines from varieties produced by crossing *Vitis vinifera* with other species of the *Vitis* genus (Gautier & Rosaz, 2014).

Despite this increasing interest in FRG, the French wine industry remains sceptical about the organoleptic quality of these new varieties, particularly red ones. Duley *et al.* (2023) have shown that the chemical composition of red FRG grapes differs from those produced by *Vitis vinifera*, which can lead to difficulties during vinification and unusual aromatic profiles. According to this author, the high protein and polysaccharide contents of FRG grapes can complicate tannin extraction and stability and produce red wines with low astringency. Furthermore, these wines can also sometimes be characterised by high acidity and excessive herbaceous or undesirable aromas (Teissedre, 2018). As new varieties and as underlined in a work conducted in the north-east of the USA (Geffroy *et al.,* 2024a), the optimal winemaking process may strongly differ in comparison with traditional varieties and research work is necessary to suit the specific characteristics of FRG varieties. According to the same author, the lack of market might be the largest obstacle regarding their adoption by winegrowers. Thus, understanding consumer preferences and acceptance of FRG wines is crucial for the wine industry.

Sensory aspects may play a crucial role in wine consumer acceptance, particularly for those made from FRG (Francis & Williamson, 2015). Concerning the use of FRG as single variety wines, it was shown that 70 % to 90 % of panellists judged their quality equivalent to that of the reference *Vitis vinifera* wines (van der Meer *et al.,* 2010). Another recent study conducted in Germany with 244 consumers and 8 different wines showed no significant difference in liking between wines made from FRG and conventional grape varieties (Kiefer & Szolnoki, 2024).

As for the use of FRG in blend also known as *coupage*, research results are still limited. While Chatelet *et al.* (2019) used original alternative sensory methods (*i.e.*, Polarised Sensory Positioning, free sorting) to characterise binary blends, their assessment by consumers was not conducted.

Ternary red blends are frequently investigated using formulas created by an augmented simplex centroid mixture design (Dooley *et al.,* 2012a; Dooley *et al.,* 2012b). For binary mixtures, successive blends are generally prepared using a base wine and a modifier wine mixed at different proportions (0–10–20...100 %) (Escudero-Gilete *et al.,* 2010). In the specific case of the use of red FRG wines for blending, the Consumer Rejection Threshold (CRT) method could be a valuable alternative for determining when the incorporation of such wines, might negatively affect consumer liking.

This latter approach relying on a series of paired preference tests was originally designed to identify when 2,4,6-trichloroanisole (TCA) becomes undesirable (Prescott *et al.,* 2005). This method has been successfully used for eucalyptol, rotundone, and 3-isobutyl-2-methoxypyrazine (IBMP) (Saliba *et al.,* 2009; Geffroy *et al.,* 2018; Geffroy *et al.,* 2020). More recently, besides aroma compounds, the method was applied to explore consumer response to a new range of ethanol reduction (Geffroy *et al.,* 2022).

The main aim of the present study was to use the CRT method to assess whether consumers accept the sensory qualities of red wine blends that incorporate resistant grape varieties. As in all the CRT research, a first experiment was conducted to determine the percentage of FRG wines that can be detected by untrained panellists in a blend. Considering that winemakers might have a greater sensitivity (Tempère *et al.,* 2019), a characteristic which could limit the use of FRG wines in red blends, such percentage was also assessed using a panel only composed of experts.

MATERIALS AND METHODS

1. Base wines

Two different wines made from red FRG were selected namely Artaban and Vidoc, some French hybrids from the ResDur 1 program (Schneider *et al.,* 2019). These red cultivars were chosen as they were the most planted red FRG in France in 2024 (Dolet *et al.,* 2024). The base wine was made from *Vitis vinifera* L. cv. Merlot, the most planted variety in 2022 to make red wine within the protected geographical indication (PGI) Pays d'Oc in the Occitanie region, south of France (https://www.paysdoc-wines.com). The three wines from the 2023 vintage were sourced from a cooperative cellar

next to Béziers, in the Occitanie region. The choice of these wines which was made in accordance with experts from the local wine industry based on their representativity was also driven by wine availabilities.

The three wines were characterised during an informal tasting session with a limited panel composed of three experts. The Artaban wine had a low colour intensity and an expressive nose featuring floral and red fruit aromas. On the palate, it exhibited a lack of viscosity and structure, with acidity being the dominant characteristic. The Vidoc wine had an intense colour and was judged as having a low-intensity nose characterised by black fruit and spicy aroma. On the palate, it was perceived as acidic, slightly bitter, thin, and astringent with 'sticky' tannins, a term referring to the negative sensation of the tongue adhering to the palate. The Merlot wine was characterised by a deep colour, high aroma intensity with prominent notes of red fruit, and fermentative aroma. On the palate, it was well-balanced with a pleasant tannic structure.

Classical oenological analyses were conducted on wines using a Winescan FT-120 technique (Foss France SAS, Nanterre France). The results are available in Table 1.

2. Determination of the percentage of wine from FRG detectable in a blend

Detection thresholds of FRG in a red blend were determined in January 2024 through two sub-sessions held over two consecutive weeks according to the American Society of Testing and Materials (ASTM) method E 679 (ASTM, 2004) for untrained and expert panellists, and for both varieties. This method which provides individual thresholds in a unique session, was chosen as it produces replicate data and makes it possible to conduct statistical analysis with the aim to investigate the impact of training and variety. The untrained panellists (n = 22) were recruited based on regular consumption of red wine (at least once a month) and were mainly staff and students from the Institut Agro Montpellier. They comprised 14 males and 7 females, aged between 23 and 64 years old not working in the wine industry. The experts (n = 23) who had extensive experience with wine tasting, were working in the wine industry and self-declared being regularly trained, comprised of 12 males and 11 females, aged between 20 and 65 years old. Participants were simply informed that they would be tasting samples of red wine.

The choice of concentration to be assessed was based on an informal tasting session with experts and untrained panellists. Blend samples were prepared with two steps between each level of incorporation. FRG wines were included in the blend at 2.5 %, 5 %, 10 % and 20 % *v/v* for experts, and at 5 %, 10 %, 20 % and 40 % *v/v* for untrained panellists, for each tested FRG. The session was organised with only four series for each FRG to minimise fatigue.

The 3-alternative forces choice (3-AFC) tests were served in increasing order of FRG incorporation, and the position of the blend sample within each test was randomised. Samples were served in clear INAO tasting glasses in a volume of 25 mL at a room temperature of around 18°C. The judges who were spaced out in a neutral room were asked to make a visual and olfactory assessment, and to place the sample in their mouth, move it for a few seconds and then spit it. Then they were asked to indicate on a questionnaire which sample of the trio was differently perceived. Panellists were given a 10-minute break between the Artaban and Vidoc series and were offered some bread to eat.

3. Determination of the percentage of wine from FRG inducing a lesser preference in a blend

The panel was composed of 53 wine consumers recruited during a wine event held at the École d'ingénieurs de Purpan in Toulouse, and from the staff of Institut Agro Montpellier. The experiment was conducted through two sub-sessions over two consecutive weeks in March 2024. The panellists did not receive remuneration for participating, and declared themselves to be regular consumers of red wine (at least once a month). No ethics approval was obtained but all participants were asked to provide written informed consent prior to participating in the study. They were just informed they had to evaluate samples of red wine. They were asked to respond to a post-tasting questionnaire to collect demographic, and wine knowledge and purchase behaviour information. The detailed composition of the panel is shown in Table 2.

TABLE 1. Classical oenological analyses conducted on the three red wines used in the study. The uncertainty of measurement is expressed as a 95 % confidence interval. TPI stands for Total Polyphenol Index.

Wine	Alcohol (% *v/v*)	pH	Total acidity (g/L as tartaric acid)	Volatile acidity (g/L of acetic acid)	Free SO_2 (mg/L)	Total SO_2 (mg/L)	Colour intensity	TPI
Merlot	14.5 ± 0.1	3.53 ± 0.05	3.7 ± 0.1	0.43 ± 0.05	23 ± 5	39 ± 5	14.3 ± 0.2	63 ± 5
Artaban	11.3 ± 0.1	3.49 ± 0.05	4.1 ± 0.1	0.53 ± 0.05	29 ± 5	44 ± 5	10.1 ± 0.2	58 ± 5
Vidoc	11.3 ± 0.1	3.39 ± 0.05	4.8 ± 0.1	0.44 ± 0.05	32 ± 5	66 ± 5	13.9 ± 0.2	49 ± 5

TABLE 2. Proportion in % of consumers by gender, age, frequency of consumption, wine preference, average amount spent on the bottle, wine knowledge, and years of consumption for the whole panel (*n* = 53).

Category		Proportion (%)
Gender	Male	51.0
	Female	49.0
Age	18–24 years	30.2
	25–34 years	17.0
	35–50 years	22.6
	51–65 years	17.0
	> 65 years	13.2
Frequency of wine consumption	Once a day	7.5
	3–4 times a week	35.8
	Once a week	47.2
	Twice a month	3.8
	Once a month	5.7
Wine preference	Red	62.4
	White	20.2
	Rosé	5.8
	No preference	11.4
Average amount spent per bottle	< 5 €	13.3
	6 to 10 €	52.8
	11 to 15 €	26.4
	> 15 €	7.5
Wine knowledge	Experts	13.2
	Interested in wine	67.9
	Newbie in wine	18.9
Years of consumption	< 5 years	24.5
	5 to 10 years	22.6
	10 to 20 years	15.2
	> 20 years	37.7

The procedure was based on a replicate series of paired preference tests (Prescott *et al.,* 2005). Each pair was composed of a wine sample of pure Merlot and a sample of the blend of Merlot with one FRG. Presentation order was randomised, and each pair was presented in ascending order of percentage of FRG wine incorporation in the blend. For both FRGs, the first level of incorporation was chosen based on the detection threshold experiment previously described for untrained panellists, with a step of two between each series. The general procedure was the same as described for the 3-AFC test with the Artaban series being tasted first, except that the panellists directly responded on their mobile phones using FIZZ Nomad v2.7 (BioSystemes, France). There was space for comments on the reason for their preference. Such an approach previously used with success by Geffroy *et al.* (2022) was preferred to traditional descriptive quantitative analysis using a trained panel for its simplicity in correlating consumer perception and liking.

4. Data treatment

The individual detection thresholds were determined for each panellist (untrained and experts) by calculating the geometric mean of the percentage of incorporation between the last failure observed and the next percentage. The panel detection threshold was then calculated as the geometric mean of these individual thresholds, in accordance with the ASTM E 679 method (ASTM, 2004).

As proposed for this method, it was assumed that a taster who had been successful at the lowest level of incorporation and at those that follow would have made a mistake at half this level. As the same, when a taster had failed at the highest level of incorporation, it was assumed that the panellist would have been correct at twice this level.

A Mann–Whitney test was conducted on the individual data to identify any differences in threshold according to FRG and level of training. This test was preferred to a Student *t*-test, as a Shapiro–Wilk test revealed that the data did not follow a normal distribution.

The percentage of FRG in the blend that induced a significantly lesser or higher preference compared to the control Merlot sample was determined using the binomial distribution for the pairwise preference test (Roessler *et al.,* 1978). If no significant preference for any tested incorporation percentage was observed, suggesting different consumer clusters, the approach by Geffroy *et al.* (2018) was implemented. Preference data were analysed by Principal Component Analysis (PCA) followed by Agglomerative Hierarchical Clustering (AHC) using the Euclidian distance and Ward's method as aggregation criterion.

For each subgroup, the proportion of consumers by gender, age, wine knowledge, and consumption habits were analysed by a Chi-square test and a Marascuilo post-hoc procedure.

The Kolmogorov–Smirnoff (two-tailed) test was used to determine if preferences for FRG blends differed according to gender, and the Kruskal–Wallis for age, wine preference, frequency of consumption, average amount spent on bottle, and level of knowledge.

These latter tests, PCA and HAC, were conducted on a matrix in which the quantitative data were the percentage of FRG incorporation of the preferred sample for each pair.

Free comments generated by the participants to explain their preferences were analysed for each FRG. According to Abric (2005), the terms were initially lemmatised and then synonyms were grouped using a triangulation procedure. Three experimenters were first tasked with grouping the terms into similar categories. Then categories were discussed until a consensus was reached to name them. Only the terms showing a citation frequency above 10 % for at least one of the test samples were retained. A Chi-square test and a Marascuilo post-hoc procedure were used to assess differences in citation frequencies of terms elicited to describe the blend in comparison with the Merlot control according to the percentage of FRG incorporation. As proposed by Geffroy *et al.* (2022), data obtained for the two varieties were treated together to have a broad overview of the sensory impact of the incorporation of FRG.

The statistical treatments were performed using XLSTAT software (Addinsoft, Paris, France).

RESULTS AND DISCUSSION

1. Detection thresholds

The distribution of individual detection thresholds according to the ASTM E 679 method for untrained and expert panellists, and for the two studied FRG is shown in Figure 1.

The detection thresholds for untrained panellists were estimated at 24.9 % for Artaban and 14.1 % for Vidoc. These thresholds were reduced for experts at 6.9 % and 7.7 % for Artaban and Vidoc, respectively, highlighting a difference in detection sensitivity between the two panels ranging from a factor of two for Vidoc to a factor of almost 3.5 for Artaban.

However, a significant difference was only observed between these two groups at $P < 0.05$ for Artaban according to the Mann–Whitney test ($P = 0.0187$ for Artaban and $P = 0.076$ for Vidoc), which somehow validates our initial hypothesis of a greater expert sensitivity. The better performance of experts in detecting resistant cultivars compared to consumers can be explained by training and wine-tasting habits, as illustrated in previous studies (Hughson & Boakes, 2002; Tempère *et al.,* 2019).

To our knowledge, no previous formal study has been conducted to investigate the minimal percentage of a modifier wine (including FRG wines) incorporated in a blend that can induce a stimulus. One of the most consistent works showed that the addition of 10 % of a varietal wine in a base wine could provoke a significant difference in perception for some specific attributes using a trained panel (Hopfer *et al.,* 2012). Specifically for FRG wines, it was demonstrated using free sorting methods and an expert panel, that small proportions of Vidoc, Artaban or Divona in

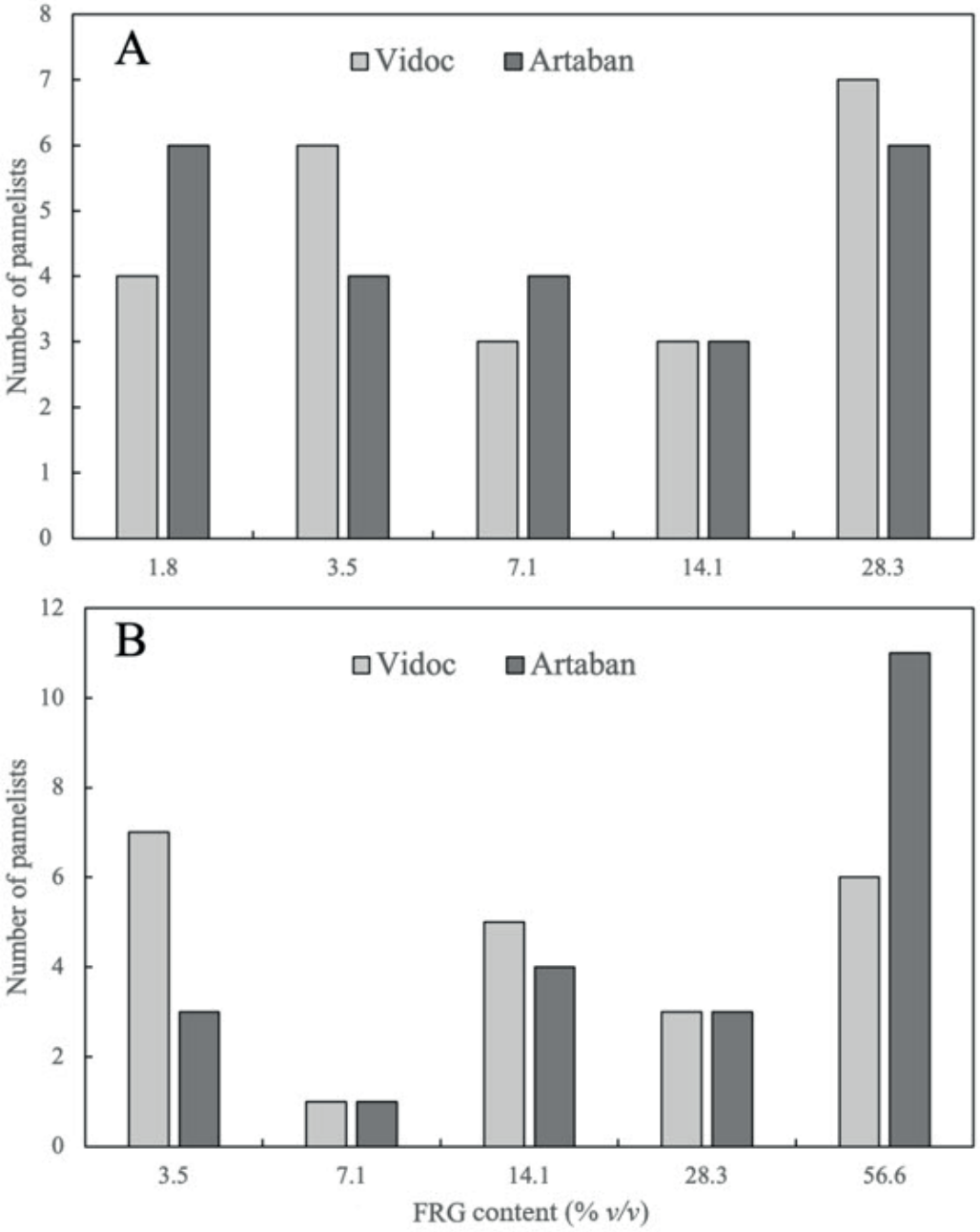


FIGURE 1. Number of panellists detecting the addition of FRG at various % in Merlot blends A) for experts (*n* = 23) and B) for untrained panellists (*n* = 22). The panel detection threshold was estimated, using the ASTM E 679 method, for experts at 6.9 % *v/v* and 7.7 % *v/v*, and for untrained panellists at 24.9 % *v/v* and 14.1 % *v/v*, for Artaban and Vidoc, respectively.

Pinot noir (*i.e.*, between 5 and 10 %), had little impact on the overall sensory characteristics of the wines compared with their pure counterparts (Chatelet *et al.,* 2019).

As for consumers, it was highlighted that such subjects were not able to perceive the inclusion of 10 to 20 % of FRG wines in a white or red blend which is consistent with our observations (Torregrosa *et al.,* 2024).

For untrained panellists, a significant difference in detection threshold was identified between the two FRG (P = 0.019) with lower values observed for Vidoc, while no difference was noticed for experts (P = 0.804). Although Total Polyphenol Index (TPI) determination on the three base wines highlighted lower values for Vidoc, which should have led to lower perceived astringency for the wines prepared with this variety, the difference in tannin quality might

have played a role. Indeed, the tannins found in Vidoc base wine were described as 'sticky' during the initial sensory evaluation of the base wines by three experts. These experts had the opportunity to taste all the wines prepared during the experiments and this specific sensory feature was also noticed in the blends prepared from Vidoc. More work would be necessary to investigate the tannin quality of wines made from FRG whose macromolecular composition may differ in comparison with conventional varieties (Duley *et al.,* 2023), and their perception by consumers.

This difference may also be explained in the light of previous research on blending (Hopfer *et al.,* 2012). Blending wines alters sensory and chemical characteristics beyond a simple averaging effect. Blends of wines with a smooth sensory profile such as Artaban may be less distinguishable from the base single-varietal wines. In contrast, blending wines with an uneven and astringent profile, such as Vidoc, may result in more pronounced differences, with suppression or amplification effects on certain attributes.

It can also be pointed out that the distribution of detection thresholds for experts tends to follow a bimodal repartition (Figure 1) with some experts—likely those frequently involved in blending activities—showing a greater sensitivity. This distribution was not observed for untrained panellists. The fact that a significant number of panellists, particularly among the untrained panel, failed to detect the different samples even at the highest level of incorporation could be attributed to sensory fatigue, as they were less accustomed to analysing fine nuances in successive series of samples (Jourjon *et al.,* 2005). However, this hypothesis is unlikely as such a phenomenon was more pronounced for the Artaban series, the first FRG blends tasted by the panellists.

It must be outlined that found detection thresholds are close for Artaban or above for Vidoc to the 15 % threshold determined by the European regulations n° 270/2002 mentioning that a varietal wine must not be made with more than 15 % of grapes from another variety than the specified one. This indicates that winemakers can incorporate FRG in Merlot wine up to that limit and continue to name the blend Merlot on the label without a majority of consumers being able to detect it at the tasting. This could be an interesting commercial strategy to benefit from the Merlot name notoriety well established on the market, a key driver of acceptance in comparison with newly developed varieties (Geffroy *et al.,* 2024b).

The percentages to be assessed in the CRT study were chosen on the basis that the first level of incorporation should be detectable by consumers. Thus, the choices of sample blends were as follows: Vidoc at 15 %, 30 %, 60 %, and 100 % *v/v* (four series of paired-test), Artaban at 25 %, 50 %, and 100 % *v/v* (three series of paired-test).

2. Appreciation of Artaban in Merlot blends by consumers

The results of the CRT study are by some means surprising for Artaban, showing a shift in preferences at a 50:50 blend ratio (Figure 2). This observation is consistent with previous work on wine blending highlighting non-linear behaviour in mixtures of compounds responsible for aroma, taste, or mouthfeel perception (Hopfer *et al.,* 2012).

Our results indicate that the blends with less than 60 % of Artaban and down to the 25 % detection limit, are significantly less preferred in comparison with the Merlot control while when Artaban exceeds 60 %, the blend is neutrally perceived with a percentage of preference close to the significance threshold of greater preference.

A total of 42 participants elicited at least one term for one of the seven wines tasted, with an average of 1.6 ± 0.8 terms per sample for these 42 panellists (Table 3). The most frequently terms used by consumers to describe the samples containing Artaban in comparison with the Merlot control were *more* or *less fruity*, *more* or *less acidic*, *more* or *less astringent,* or *less balanced*. This lack of consensus for the fruity character, acidity and astringency illustrates the difficulty encountered by consumers in describing their perception.

Overall, although nonlinearity was observed, the sample containing only Artaban (100 % *v/v*) was described on average as being *more fruity* and *more acidic* which is in accordance with the initial sensory description and the oenological analyses of the three base wines (Table 1). This overall neutral perception of pure Artaban wine is rather interesting, especially considering that fruitiness has proven to be a key appreciation driver for most consumers (Francis & Williamson, 2015) and acidity is now also valued by consumers for its role in enhancing the freshness and balance of red wines (Regnerová & Hes, 2016).

As a consequence of being perceived in trend *less fruity* than the other Artaban blends, one characteristic generally negatively correlated with liking as previously discussed, the blend prepared with 50 % Artaban was preferred by the lowest proportion of consumers.

The test sample containing 25 % of Artaban tends to be judged as *less balanced, less astringent* which could explain the significantly lesser preference observed. Indeed, in addition to the overall lack of balance which is likely to affect consumer acceptance (Francis & Williamson, 2015), the perceived low astringency may also have played a role, as astringency is considered a desirable attribute by many wine consumers (Villamor *et al.,* 2009). However, the reasons why such a blend lacks balance remain unclear and would deserve further studies. It can be mentioned that no term related to colour was elicited, a characteristic that could have discriminated the blends and impacted consumers' liking (Dooley *et al.,* 2012a) given the low colour intensity of Artaban (Table 1).

Non-parametric tests showed that preferences were not significantly influenced by gender, purchasing habits, wine frequency and preference (Table 3). Age had a significant influence on preference, with the youngest panellists (between 18 and 24), compared to older ones (> 65), preferring the blend containing 50 % of Artaban that exhibits in trend less

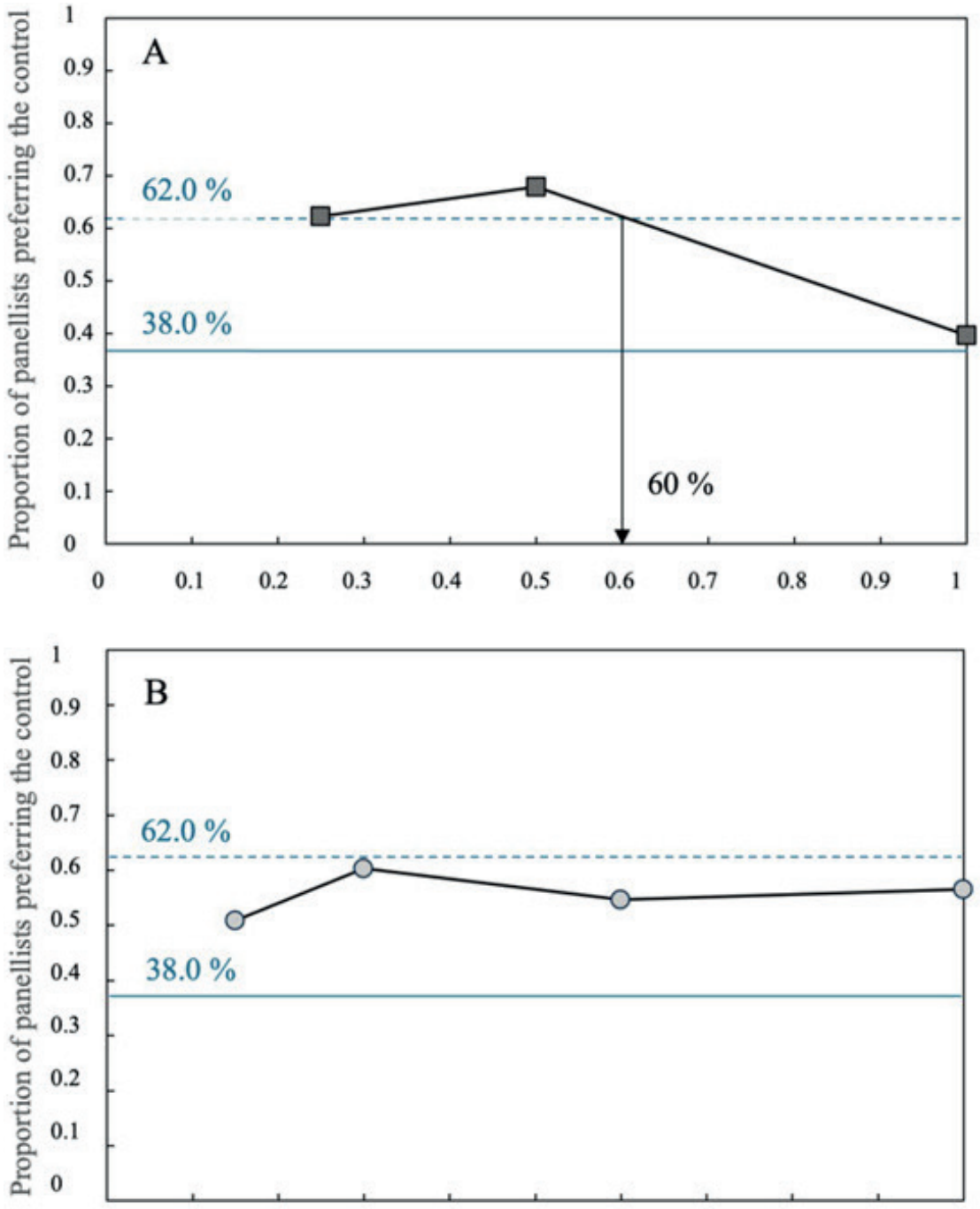


FIGURE 2. Proportion of panellists preferring the control Merlot sample in comparison with A) Artaban and B) Vidoc blends. Above the top horizontal dotted line at 62 %, the control Merlot is significantly preferred, and below the bottom horizontal solid line at 32 %, the blend is significantly preferred at 5 % risk using paired comparison tests (n = 53).

fruity aroma. This is in contradiction with previous results showing that fruity note is a key driver of liking for such young consumers in red wine (Geffroy *et al.,* 2024b).

Although this approach relying on non-parametric tests to identify consumer profiles has been used in several studies (Saliba *et al.,* 2009; Geffroy *et al.,* 2018; Geffroy *et al.,* 2020; Geffroy *et al.,* 2022), these findings must be considered and interpreted with caution as the small number of consumers in each subgroup may limit the representativeness of the samples.

3. Appreciation of Vidoc in Merlot blends by consumers

Surprisingly, the incorporation of Vidoc in the blend did not lead to a lesser significant preference in comparison with the control Merlot sample for all the percentages of incorporation evaluated which contradicts our initial hypothesis (Figure 2). This result is unexpected, considering the tannin quality of Vidoc wines, which were described as 'sticky' and might have negatively influenced consumer liking as their proportion in the blend increased.

TABLE 3. Citation frequencies (expressed in %) for the terms used by consumers to describe the Artaban and Vidoc blends in comparison with the control Merlot wine, and significance *(P)* calculated from the Chi-square test within each term. Only the terms showing a citation frequency above 10 % for at least one test sample were retained. Different letters within each line indicate significant differences based on the post-hoc Marascuilo test.

Term	Artaban (% *v/v*)			Vidoc (% *v/v*)				*P*
	25	50	100	15	30	60	100	
More fruity	10.0 ab	13.2 b	21.1 b	0.0 a	11.9 ab	11.3 ab	5.3 ab	0.022
Less fruity	16.0 c	18.4 c	7.9 abc	12.3 bc	0.0 a	1.6 b	0.0 a	< 0.001
Less acidic	10.0 ab	5.3 ab	10.5 b	0.0 a	0.0 a	0.0 a	0.0 a	0.002
More acidic	10.0 ab	15.8 ab	21.1 ab	10.8 ab	16.4 ab	6.5 a	28.1 b	0.041
Sweeter	0.0 a	0.0 a	0.0 a	6.2 ab	9.0 ab	16.1 b	7.0 ab	0.001
More astringent	6.0	18.4	15.8	7.7	6.0	16.1	5.3	0.090
Less astringent	14.0	10.5	7.9	7.7	9.0	3.2	3.5	0.397
Rounder	0.0 a	0.0 a	0.0 a	6.2 ab	14.9 b	6.5 ab	12.3 b	0.001
Less balanced	12.0 b	2.6 ab	2.6 ab	0.0 a	0.0 a	0.0 a	0.0 a	< 0.001
More pleasant	0.0 a	0.0 a	0.0 a	7.7 ab	7.5 ab	12.9 b	14.0 b	0.002

As for the detection threshold experiment, it cannot be discarded that the relatively large number of samples tasted by the consumers during the session (14 in total) induced some fatigue which generates some noise in the dataset for Vidoc that was tasted after Artaban. However, this hypothesis is unlikely as such number remains acceptable according to Francis and Williamson (2015) who recommend not to exceed 10 to 14 wines per session.

As for Artaban and as expected, the inclusion of Vidoc in the blend increased non-linearly the perception of acidity (Table 3). Other terms frequently expressed by consumers to characterise the Vidoc blends were *more fruity*, *less fruity*, *sweeter*, *rounder*, and *more pleasant* with a linear relationship between the proportion of incorporation and the citation frequency only observed for this latter term.

As shown in Table 4, the 30 % Vidoc blend was preferred by consumers who had a basic interest in wine, compared to those who were either new to wine or had a more passionate, in-depth knowledge, a finding which is difficult to interpret. In comparison, experienced panellists with more than 20 years of wine consumption preferred the 15 % Vidoc blend which was perceived as *less fruity*, unlike consumers with 5 to 10 years of experience.

Preferences for Vidoc blends seemed to be influenced by experience and wine knowledge. Indeed, it has been shown that preferences change with experience, with new consumers initially preferring sweet, fruity wines, and over time appreciating bitterness (a characteristic outlined in the initial description of the Vidoc base wine) and green aroma (Lesschaeve, 2008).

The PCA followed by HAC enabled the identification of four subgroups of Vidoc consumers, C1, C2, C3 and C4. The proportion of panellists preferring the Merlot control was plotted for each subgroup (Figure 3). Given the limited number of panellists for each subgroup, the Chi-square and post-hoc Marascuilo tests only enabled to discriminate at $P < 0.05$ the four subgroups for their proportions in subjects interested in wine, newbies in wine and those consuming wine once a day. Consumers from C1 (n = 16), neutrally perceived Vidoc blends with a preference for blends with a

TABLE 4. Significance *(P)* of preference for each proportion of FRG included in the blend for gender, age, level of wine knowledge, average amount spent per bottle, frequency of wine consumption, wine preference, and years of wine consumption (n = 53 consumers). The Kruskal–Wallis test was performed except for gender which was treated using the Kolmogorov–Smirnoff (two-tailed) test.

	FRG content (% v/v)	Gender	Age	Level of wine knowledge	Average amount spent per bottle	Frequency of wine consuming	Wine preference	Years of wine consumption
Artaban	25	1.000	0.117	0.866	0.534	0.224	0.214	0.810
	50	0.985	0.018	0.959	0.254	0.099	0.457	0.233
	100	1.000	0.272	0.981	0.426	0.289	0.790	0.249
Vidoc	15	1.000	0.061	0.891	0.709	0.167	0.934	0.038
	30	0.642	0.748	0.009	0.624	0.585	0.730	0.862
	60	1.000	0.503	0.400	0.814	0.068	0.076	0.507
	100	0.979	0.075	0.155	0.381	0.149	0.230	0.303

Vidoc proportion between 15.0 % and 39.0 %. Consumers in this subgroup predominantly expressed an interest in wine (87.5 %) and included a moderate proportion of daily wine drinkers (6.3 %).

C2 (n = 13) had a more complex preference profile. They preferred Merlot in comparison with the blend, especially when Vidoc was incorporated at a percentage between 27.7 % and 37.5 %, and preferred Vidoc blend below 17.3 % of incorporation. It can be assumed that Vidoc was generally not perceived at this percentage as illustrated by its detection threshold previously determined at 14.1 % for untrained panellists. Results remain overall difficult to interpret with a notable lack of consistency and significant variations in responses that do not seem to follow an explainable logic which could mean that participants responded randomly. Subjects from this subgroup were not daily wine-drinkers (0.0 %), and self-declared themselves as mainly newbies in wine for 61.5 % or interested in wine for 30.8 %.

The third cluster C3 (n = 13) showed distinct and more defined sensory preferences. They preferred pure Merlot wines when Vidoc was incorporated at less than 21 %, a percentage close to the Vidoc detection threshold in the blend. They were not daily wine drinkers (0.0 %) and mostly declared themselves to be newbies (46.1 %) or interested in wine (38.5 %).

C4 (n = 11) also showed a clearly defined taste preference for the Merlot control. These "Merlot lovers" exhibited a greater frequency of daily consumption (27.3 %), and declared themselves as more newbie in wine (72.7 %). Although not statistically significant (P = 0.090), this cluster tended to include a higher proportion of consumers over the age of 65. This subgroup seems to represent consumers with established consumption habits, who seek familiarity and balance in their wine choices, favouring traditional profiles like Merlot wine over more acidic, astringent wines like Vidoc. Indeed, for this subgroup, the most elicited terms to describe the Vidoc blends in comparison with Merlot were *more acidic* and *more astringent* with citation frequencies reaching 23.1 % for the blend containing 60 % of Vidoc and the pure Vidoc sample, respectively.

To summarise, Vidoc consumers can be divided into two main groups of preferences: "the neutral" representing 79 % of the panellists composed of C1, C2 and C3 for which it appears feasible to incorporate Vidoc into the blend; "the Merlot lovers" composed of C4 consumers, which represented 21 % of the panellists, and always preferred Merlot wines. These latter consumers were characterised by the highest proportion of daily wine drinkers and newbies in wine.

However, these results based on subgroups composed of 11 to 16 panellists should be treated with caution as CRT studies are generally conducted with 50 to 60 panellists (Prescott *et al.,* 2005; Geffroy *et al.,* 2018). The likelihood of a significant result by chance especially for the smallest group (C4) cannot completely be excluded. In addition, the clustering may have simply detected artefacts such as those individuals who have a specific sample presentation order or those individuals susceptible to fatigue. This hypothesis is unlikely, as there was a strong consensus within the C4 cluster with all panellists preferring the control wine (Figure 3D), regardless of the proportion of Vidoc in the blend. It must also be highlighted that one of the main risks when working with small panels as underlined by Talsma (2018) is the potential for Type II errors which means failing to detect real effects and to reject the null

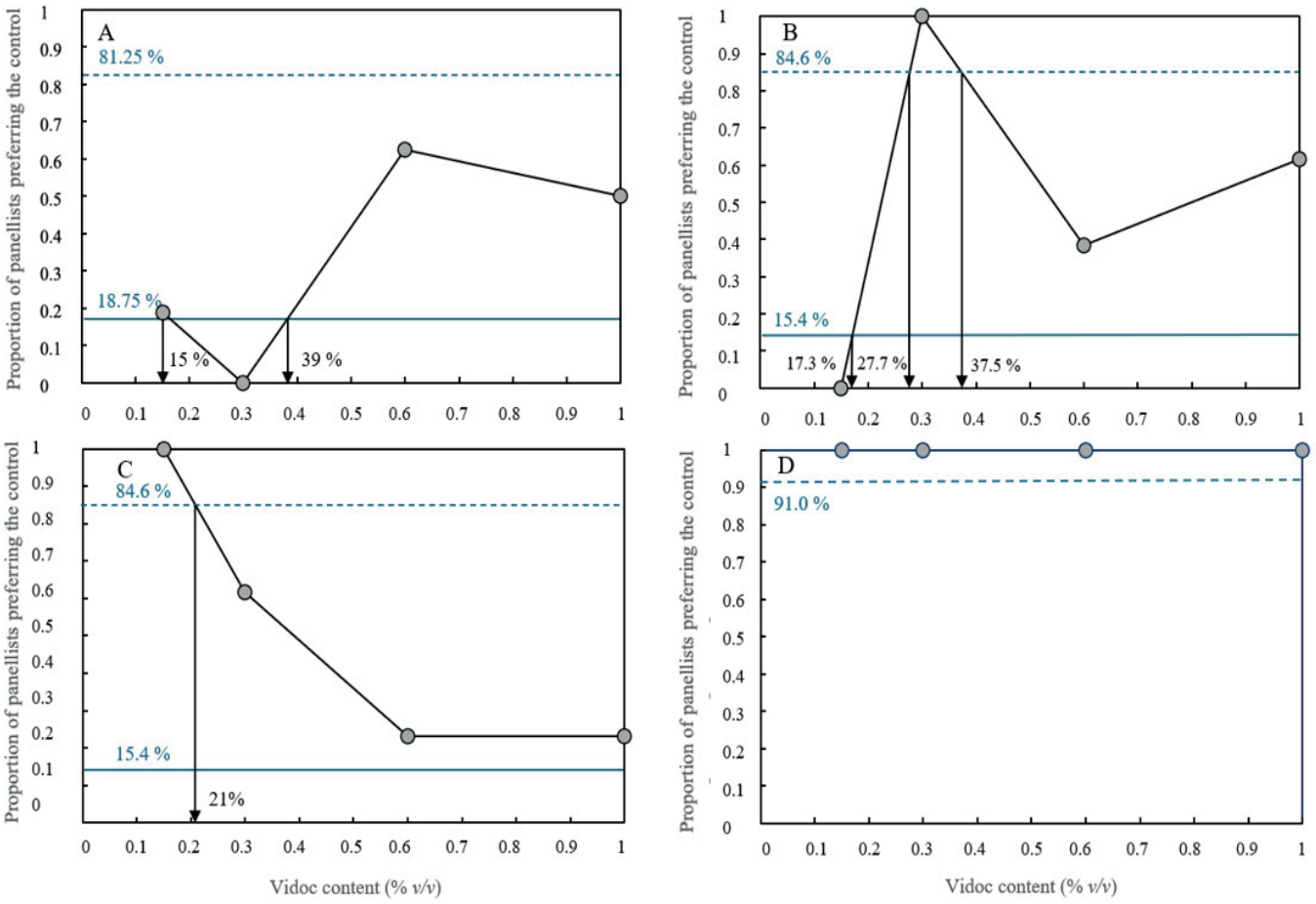


FIGURE 3. Proportion of panellists preferring the control Merlot wine for the four subgroups, C1 (A), C2 (B), C3 (C) and C4 (D). Above the top horizontal dotted line, the control Merlot is significantly preferred, and below the bottom horizontal solid line, the blend is significantly preferred at 5 % risk using paired comparison.

hypothesis. The fact that significant differences were observed despite a relatively small sample tends to support the interest in presenting these findings.

Our findings, emphasising an overall good acceptance of FRGs and weakening the negative preconceptions about these varieties emerging from the wine industry, are only valid for the three specific base wines used for the study.

Despite their good representativity, the Vidoc and Artaban wines were made from two young vineyard plots, suggesting that their sensory features could evolve over time with the ageing of the vineyard. The 2023 vintage was the first commercial harvest for Vidoc and the fourth one for Artaban. Furthermore, this vintage faced challenging conditions, with heavy rainfall in June that led to high downy mildew pressure, elevated acidity, and an early harvest. It cannot be excluded that a higher-quality vintage might yield different results and particularly an even greater acceptability of FRG wines in blends.

The influence of the Merlot base wine, which was very ripe, containing an ethanol level above 14 % *v/v*, must also be considered. However, such a level of ethanol is very frequent in the area characterised by a Mediterranean climate, and warm and dry climatic conditions during maturation favour sugar accumulation. The marked difference in ethanol between this latter wine and the Artaban and Vidoc wines (Table 1) might have contributed to favour the detection of FRG wines in blends. It cannot be excluded that the use of a control wine with a lower ethanol concentration could have led to distinct conclusions.

Our methodology was focused on red FRG wines and might not be transposable to white FRG wines. Probably, no significantly lesser preference in comparison with a *Vitis vinifera* control wine would have been observed for white FRG blends. Indeed, white FRG varieties are generally considered superior (Torregrosa *et al.,* 2024) and are getting more and more popular in southern France as illustrated by the fast increase in Floreal planting, another variety obtained within the frame of the ResDur 1 program particularly appreciated for its very pleasant aromatic profile (Dolet *et al.,* 2024).

Our study showed that experts were more sensitive compared to consumers, a characteristic that should also influence their preferences that were not evaluated in our research. This assessment would have been particularly hard to achieve as it would have involved mobilising fifty experts for the CRT study. Nevertheless, one must keep in mind that consumer responses truly reflect the acceptance of a product on the market, and the perceptions of specialists are generally disconnected from those of the general population (Cardello, 1995).

Another point of great interest would be to formally examine the sensory acceptance of a larger range of pure variety FRG wines and the impact of information provided to consumers on their acceptance. Although the impact of information related to the environmental benefits provided by these FRG varieties has been studied using experimental auctions (Espinoza *et al.,* 2018), the influence of other information such as the resistant or hybrid characters of these varieties deserves to be investigated.

CONCLUSION

Our study enabled to apply the CRT methodology to the design of binary red blends containing FRG wines. The panel detection thresholds for red FRG wines in a Merlot blend were estimated at 24.9 % for Artaban and 14.1 % for Vidoc for untrained panellists. Concerning consumer preferences, wines with a high proportion of Artaban in the blend (> 60 %) were neutrally perceived in comparison with Merlot wines. For Vidoc, the results showed the absence of significantly lesser preference for all the tested blends, suggesting an overall good sensory acceptance and the existence of different clusters of consumers. Four subgroups were identified with heterogeneous profiles exhibiting complex or clear preferences. Only one group, representing 21 % of consumers composed of a higher proportion of daily wine drinkers and self-declared newbies in wine, significantly preferred Merlot over Vidoc blends, and would not accept Vidoc used as a single variety wine or in a blend. Overall, based on these results showing the absence of any strong sensory obstacles and a good consumer acceptability of FRG wines, winemakers should be encouraged to use resistant variety in blend or even in single *cuvée*.

Further research is required to investigate the sensory perception of pure FRG wines and the influence of information on consumer acceptance to provide valuable insights for producers and wine professionals in the design and marketing of these new products.

ACKNOWLEDGEMENTS

The authors would like to thank the Occitanie Region for funding the Ressenti project through the Défi Clé Vinid'Occ and notably half of the doctoral thesis grant of Caroline Paire. The authors also acknowledge the Vignobles Foncalieu and Grands Chais de France for additional funding. They are also grateful to the panellists from École d'ingénieurs de Purpan, Institut Agro Montpellier, to the experts from "La Maison des Vins de Gaillac," from Foncalieu and Grand Chai de France, and to all the consumers who participated in the study. Filippo Fiocchetti, Marc-Antoine Dolet, Maeva Podworny, and Maud Caperaa are also acknowledged for their technical support.

REFERENCES

Abric, J.-C. (2005). La recherche du noyau central et de la zone muette des représentations sociales. In *Méthodes d'étude des représentations sociales* (pp. 59-80). Érès. https://doi.org/10.3917/eres.abric.2003.01.0059

ASTM (2004). Standard practice E 679–04. Standard practice for determination of odor and taste thresholds by a forced-choice ascending concentration series method of limits. Philadelphia, PA: American Society for Testing and Materials.

Borrello, M., Cembalo, L., & Vecchio, R. (2021). Consumers' acceptance of fungus resistant grapes: Future scenarios in sustainable winemaking. *Journal of Cleaner Production*, *307*, 127318. https://doi.org/10.1016/j.jclepro.2021.127318

Cardello, A. V. (1995). Food quality: Relativity, context and consumer expectations. *Food Quality and Preference*, *6*(3), 163170. https://doi.org/10.1016/0950-3293(94)00039-X

Chatelet, B., Otheguy, M., & Honoré-Chedozeau, C. (2019). Comment les méthodes sensorielles innovantes peuvent-elles contribuer au déploiement de variétés résistantes en France ? *BIO Web of Conferences*, *15*, 02027. https://doi.org/10.1051/bioconf/20191502027

Dolet, M. A., Paire, C., Cheriet, F., Geffroy, O., Le Fur, Y., Hannin, H., Samson, A., Caillé, S., Nougarède, S., Olivier, V. & Chervin, C. (2024). Resumption of the planting of grapevine varieties in France, referred to as" disease-resistant": Original language of the article: English. *IVES Technical Reviews, vine and wine*. https://doi.org/10.20870/IVES-TR.2024.8261

Dooley, L. M., Threlfall, R. T., Meullenet, J. F., & Howard, L. R. (2012a). Compositional and sensory impacts from blending red wine varietals. *American Journal of Enology and Viticulture*, 63(2), 241-250. https://doi.org/10.5344/ajev.2012.11086

Dooley, L., Threlfall, R. T., & Meullenet, J. F. (2012b). Optimization of blended wine quality through maximization of consumer liking. *Food Quality and Preference*, *24*(1), 40-47. https://doi.org/10.1016/j.foodqual.2011.08.010

Duley, G., Ceci, A., Longo, E., & Boselli, E. (2023). Oenological potential of wines produced from disease-resistant grape cultivars. *Comprehensive Reviews in Food Science and Food Safety*, *22*. https://doi.org/10.1111/1541-4337.13155

Escudero-Gilete, M. L., González-Miret, M. L., & Heredia, F. J. (2010). Implications of blending wines on the relationships between the colour and the anthocyanic composition. *Food Research International*, *43*(3), 745-752. https://doi.org/10.1016/j.foodres.2009.11.004

Espinoza, A. F., Hubert, A., Raineau, Y., Franc, C., & Giraud-Héraud, É. (2018). Resistant grape varieties and market acceptance: An evaluation based on experimental economics. *OENO One*, *52*(3), Article 3. https://doi.org/10.20870/oeno-one.2018.52.3.2316

Francis, I. l., & Williamson, P.O. (2015). Application of consumer sensory science in wine research. *Australian Journal of Grape and Wine Research*, *21*(S1), 554567. https://doi.org/10.1111/ajgw.12169

Gautier, J., & Rosaz, E. (2014). L'évolution de l'encépagement des indications géographiques françaises : Outils de gestion du vignoble et contraintes subies. *37th World Congress of Vine and Wine and 12th General Assembly of the OIV*, 07009. https://doi.org/10.1051/oivconf/201407009

Geffroy, O., Armario, M., Fontaine, A., Fourure, M., Pasquier, G., Semadeni, T., & Chervin, C. (2020). 3-Isobutyl-2-methoxypyrazine is neutrally perceived by consumers at usual concentrations in French Sauvignon and Fer wines from the Gaillac area. *OENO One*, *54*(4), 11331142. https://doi.org/10.20870/oeno-one.2020.54.4.4492

Geffroy, O., Cheriet, F., Chervin, C., Hannin, H., Olivier, V., Samson, A., & Vanden Heuvel, J. (2024a). Opportunities and challenges in the adoption of new grape varieties by producers: a case study from the Northeastern United States. *IVES Conference Series, OIV 2024*.

Geffroy, O., Descôtes, J., Serrano, E., Li Calzi, M., Dagan, L., & Schneider, R. (2018). Can a certain concentration of rotundone be undesirable in Duras red wine? A study to estimate a consumer rejection threshold for the pepper aroma compound: Consumer rejection threshold for rotundone in Duras wine. *Australian Journal of Grape and Wine Research*, *24*(1), 8895. https://doi.org/10.1111/ajgw.12299

Geffroy, O., Laforge, J., Denat, M., Guérin, L., & Peter, M. (2024b). Are peppery notes the main negative driver of liking for young French consumers in a Duras red wine made from a cool and wet season? *OENO One*, *58*. https://doi.org/10.20870/oeno-one.2024.58.1.7729

Geffroy, O., Pasquier, G., Pagès, M., & Violleau, F. (2022). Exploring the response to a new range of ethanol reductions in Chardonnay and Syrah wines using a Consumer Rejection Threshold approach. *OENO One*, *56*(4), 147155. https://doi.org/10.20870/oeno-one.2022.56.4.7112

Hopfer, H., Ebeler, S. E., & Heymann, H. (2012). How Blending Affects the Sensory and Chemical Properties of Red Wine. *American Journal of Enology and Viticulture*, *63*(3), 313324. https://doi.org/10.5344/ajev.2012.11112

Hughson, A. L., & Boakes, R. A. (2002). The knowing nose: The role of knowledge in wine expertise. *Food Quality and Preference*, 13(78), 463472. https://doi.org/10.1016/S0950-3293(02)00051-4

Jourjon, F., Symoneaux, R., Thibault, C., & Reveillere, M. (2005). Comparison of different scaling techniques for sensory analysis of wines. *OENO One*, *39*(1), 23. https://doi.org/10.20870/oeno-one.2005.39.1.906

Kiefer, C., & Szolnoki, G. (2024). Influence of information about fungus-resistant grape varieties on hedonic ratings by consumers – a central location test in Germany. *Wine Economics and Policy*, *13*(2), Article 2. https://doi.org/10.36253/wep-16110

Lesschaeve, I. (2008). Wine consumer flavour preferences, in Chassagne D (ed.), *1st Wine Active Compounds Symposium*. Beaune, France, OenoPluri Media, 71–74.

Paire, C., Dolet, M., Hannin, H., Samsom, A., Olivier, V., Chervin, C., Geffroy, O., & Cheriet, F. (2024). History of breeding programmes for fungus resistant grape varieties in Europe, France and the Occitanie region. IVES Technical Reviews. https://doi.org/10.20870/ives-tr.2024.8262

Prescott, J., Norris, L., Kunst, M., & Kim, S. (2005). Estimating a "consumer rejection threshold" for cork taint in white wine. *Food Quality and Preference*, 16(4), 345-349. https://doi.org/10.1016/j.foodqual.2004.05.010

Regnerová, O., & Hes, A. (2016). Current trends in the global wine market. *In International Scientific Days 2016*: The Agri-Food Value Chain—Challenges for Natural Resources Management and Society (pp. 820-827). Slovak University of Agriculture in Nitra. https://doi.org/10.15414/isd2016.s10.07

Roessler, E., Pangborn, R., Sidel, J., & Stone, H. (1978). Expanded statistical tables for estimating significance in paired—preference, paired–difference, duo–trio and triangle tests. *Journal of Food Science*, 43(3), 940-943. https://doi.org/10.1111/j.1365-2621.1978.tb02458.x

Saliba, A. J., Bullock, J., & Hardie, W. J. (2009). Consumer rejection threshold for 1, 8-cineole (eucalyptol) in Australian red wine. *Food Quality and Preference*, 20(7), 500-504. https://doi.org/10.1016/j.foodqual.2009.04.009

Schneider, C., Onimus, C., Prado, E., Dumas, V., Wiedemann-Merdinoglu, S., Dorne, M. A., Lacombe, M. C., Piron, M. C., Umar-Faruk, A., Duchêne, E., Mestre, P., & Merdinoglu, D. (2019). INRA-ResDur: The French grapevine breeding programme for durable resistance to downy and powdery mildew. Acta Horticulturae, 1248, 207–214. https://doi.org/10.17660/ActaHortic.2019.1248.30

Talsma, P. (2018). How much sensory panel data do we need? *Food Quality and Preference*, 67, 3-9. https://doi.org/10.1016/j.foodqual.2016.12.005

Teissedre, P. L. (2018). Composition of grape and wine from resistant vines varieties. *OENO One*, *52*(3), 211-217. https://doi.org/10.20870/oeno-one.2018.52.3.2223

Tempère, S., de Revel, G., & Sicard, G. (2019). Impact of learning and training on wine expertise: A review. *Current Opinion in Food Science*, *27*, 98103. https://doi.org/10.1016/j.cofs.2019.07.001

Töpfer, R., Hausmann, L., Harst, M., Maul, E., Zyprian, E., & Eibach, R. (2011). New horizons for grapevine breeding. *Fruit, Vegetable and Cereal Science and Biotechnology*, 5(1), 79-100.

Torregrosa, L., Lacombe, T., & Ojeda, H. (2024). Vignes tolérantes aux maladies fongiques : des variétés à fruits pour une viticulture en transition agroécologique (1st ed.). Editions France Agricole.

van der Meer, M., Weibel, F., Lévite, D., Häseli, A., Vombach, D., & Wyss, D. (2010). Acceptation des vins de cépages résistants pas les consommateurs, Résultats du projet TOPiwi 2007-2008. *Revue suisse Viticulture, Arboriculture, Horticulture*, *42(2)*, 147150.

Villamor, R. R., Harbertson, J. F., & Ross, C. F. (2009). Influence of tannin concentration, storage temperature, and time on chemical and sensory properties of Cabernet Sauvignon and Merlot wines. *American Journal of Enology and Viticulture*, *60*(4), 442-449. https://doi.org/10.5344/ajev.2009.60.4.442

Wei, R., Wang, L., Ding, Y., Zhang, L., Gao, F., Chen, N., ... & Wang, H. (2023). Natural and sustainable wine: a review. *Critical Reviews in Food Science and Nutrition*, *63*(26), 8249-8260. https://doi.org/10.1080/10408398.2022.2055528